SECTION 02779

GEOSYNTETIC CLAY LINERS

PART 1--GENERAL

1.01 DESCRIPTION

This section specifies the geosynthetic clay liners (GCL) to be installed as the sub-base beneath Municipal Solid Waste (MSW) Cell 1 of the Phase III Landfill at the Lake County Solid Waste Management Facility. The Contractor shall provide the manufacturing, factory testing and certification, and installation of the GCL component of the landfill liner system as specified herein. Sampling and testing of installed liner system components shall be coordinated with the Construction Quality Assurance (CQA) Contractor as provided for in the CQA Plan in Section 01900.

1.02 RELATED SECTIONS

A. SECTION 01900, CONSTRUCTION QUALITY ASSURANCE
B. SECTION 02200, EARTHWORK
C. SECTION 02777, HIGH DENSITY POLYETHYLENE GEOMEMBRANE
D. SECTION 02778, GEOCOMPOSITES, GEOTEXTILES AND GEONETS

1.03 REFERENCES

This section contains references to the following documents produced by the American Society for Testing and Materials (ASTM), the Geosynthetic Research Institute (GRI), and the United States Environmental Protection Agency (USEPA). These references are a part of this section as specified and modified. In case of conflict between the requirements of this section and those of the listed documents, the requirements of this section shall prevail. Requirements of the latest edition of these documents shall be used.

Reference	Title
ASTM D 4354	Practice for Sampling of Geosynthetics for Testing
ASTM D 4439	Terminology for Geosynthetics
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
ASTM D 4643	Determination of Water (Moisture) Content of Soil by the Microwave Oven Method
ASTM D 5084	Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a

Reference	Title
	Flexible Wall Permeameter
ASTM D 5261	Standard Test Method for Measuring Mass Per Unit Area of Geotextiles
ASTM D 5321	Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method
ASTM D 5887	Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter
ASTM D5888	Practice for Storage and Handling of GCLs
ASTM D5890	Test Method for Swell Index of Clay Mineral Component of GCL
ASTM D5891	Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liner
ASTM D5993	Standard Test Method for Measuring Mass per Unit Area of Geosynthetic Clay Liner
ASTM D6102	Guide for Installation of Geosynthetic Clay Liners
ASTM D6243	Methods for Determining the Internal and Interface Shear Resistance of GCL by the Direct Shear Method
ASTM D6495	Guide for Acceptance Testing Requirements for GCL
ASTM D 6496	Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners
ASTM D6766	Test Method for Evaluation of Hydraulic Properties of GCL Permeated with Potentially Incompatible Liquids
ASTM D6768	Test Method for Tensile Strength of GCL

Relevant publications from the Environmental Protection Agency (EPA):

Reference:

Daniel, D.E. and R.M. Koerner, (1993), *Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities,* EPA/600/R-93/182.

1.04 QUALITY ASSURANCE/QUALITY CONTROL

A. GENERAL

This section requires that the manufacturing, fabrication, delivery, and installation of the GCL components of the landfill liner system be done in strict compliance with a comprehensive Quality Assurance/Quality Control (QA/QC) program. The QA/QC program shall include the manufacturer's quality control (MQC) procedures, the Contractor's construction quality control (CQC) procedures, and the CQA Plan which is provided in Section 01900 of these specifications.

The goal of the QA/QC program is to provide assurance to the Florida Department of Environmental Protection (FDEP) and the Owner that the landfill liner system meets or exceeds all FDEP regulatory requirements and that the system has been manufactured, fabricated and installed to satisfy all provisions of these specifications.

The QA/QC program shall provide documentation of all inspections and tests, such that each component installed in the landfill liner system can be traced through the entire process from raw material delivery to the manufacturer through installation. It is intended that the GCL Manufacturer install this component of the landfill liner system using either personnel employed by the GCL Manufacturer or contractors certified by the GCL Manufacturer and manufacturers of the other geosynthetics to install materials for which they are responsible.

B. MINIMUM EXPERIENCE REQUIREMENTS

The GCL specified herein shall be supplied by a Manufacturer/Installer having a minimum of 5 years experience in the manufacture and installation of GCL. The GCL Manufacturer/Installer shall have documented evidence of the manufacture and installation of a minimum of 10 million square feet of GCL as specified herein. The Installation Supervisor assigned to this project shall have been responsible for the installation of a minimum of 10 million square feet of GCL, 5 million square feet of which must have been on solid waste landfill applications.

C. LINER SYSTEM GUARANTEE

1. MATERIALS:

a. The manufacturers of GCL material to be supplied as components of the landfill liner system shall guarantee their materials against deterioration or defects for 5 years from the date of acceptance. The guarantee shall be against defects in material or workmanship and against deterioration due to ozone, ultraviolet light, leachate, bacteria and other processes after adhering to

manufacturer's recommendations for storage and installation.

b. The guarantees shall be made, in writing, directly to the Owner (not the Contractor), and in a format acceptable to the Owner.

2. INSTALLATION:

a. The Contractor and the GCL Manufacturer/Installer shall guarantee the installation workmanship of the entire landfill liner system for a minimum of 2 years from the date of acceptance by the Owner.

b. The guarantee shall be made directly to the Owner in a format acceptable to the Owner.

D. LINER SYSTEM CERTIFICATION

Upon completion of the Project, the Contractor and the GCL Manufacturer/Installer shall certify, in writing, that the installed GCL materials satisfy the requirements of these specifications and the CQA Plan.

E. MANUFACTURER'S QUALITY CONTROL (MQC) PLAN

The GCL Manufacturer/Installer and Contractor shall submit a MQC Plan for the manufacture of all geosynthetic components of the landfill liner system. Submittal of the MQC Plan shall be as required in Paragraph 1.06B.

The MQC Plan shall contain the following minimum information on each of the geosynthetic materials to be supplied as components of the landfill liner system:

1. General description of the GCL Manufacturer's and other geosynthetic manufacturer's MQC organization, personnel and facilities.

2. Inspection, sampling, testing and report procedures for evaluating the quality of raw materials used in the manufacture of the components used in this project.

3. Inspection, sampling, testing and report procedures for evaluating the quality of the finished products during manufacture.

4. Inspection, sampling, testing and report procedures for evaluating factory seams and seaming equipment during fabrication (if required), and methods and procedures for correcting defective seams.

5. Inspection and report procedures for evaluating and correcting damage to the components during storage at the factory and/or delivery to the job site.

The Contractor shall supply a copy of all MQC Plans to the CQA Contractor for review with respect to the requirements of the CQA Plan.

1.05 TESTING

A. MATERIAL PROPERTIES TESTING

Test methods and sampling frequencies for the GCL are presented in Tables 1 and 2 at the end of this Section. Test methods and sampling frequencies for soil materials are presented in Section 02200. Test methods and sampling frequencies associated with CQA during installation of the landfill liner system are presented in the CQA Plan in Section 01900.

Acceptance testing of the GCL shall be in conformance with ASTM D6495 and the interface friction angle testing requirements described in Sections 02777 and 01900.

B. RESPONSIBILITY FOR SAMPLING AND TESTING

The Contractor is responsible for the cost of testing of liner system materials, including that identified in Table 1 of this Section, the interface friction angle testing identified above, and the soil material testing identified in Section 02200. The Owner is responsible for the cost of independent testing required by the CQA Plan, including conformance testing of geosynthetic materials delivered to the jobsite, laboratory testing of field seams joining geosynthetics.

The Contractor is responsible for sampling for all tests specified in this Section, the CQA Plan, and any subsequent testing of a particular section after reworking. Samples shall be taken at locations identified or approved by the CQA Contractor. Destructive test sample locations shall be repaired immediately after sampling. All factory tests specified shall be performed at the manufacturer's expense. Additional laboratory or field tests, including conformance testing as required in the CQA Plan, which, in the opinion of the Engineer, are necessary to confirm compliance with the requirements of these specifications, shall be conducted at the Owner's expense. The Contractor and material manufacturer shall provide access and samples needed for conducting these additional tests.

1.06 SUBMITTALS

A. GENERAL

Submittals shall be transmitted to the Engineer in accordance with the requirements of Section 01300 and shall include the information specified below.

Submittals shall use standard terminology as established in ASTM D4439.

B. GEOSYNTHETIC MATERIALS

Four submittals shall be provided regarding the GCL of the landfill liner system.

1. FIRST SUBMITTAL: Within 60 calendar days after construction contract notice to proceed, the GCL Manufacturer/Installer and Contractor shall submit the following information on the GCL material in the landfill liner system:

a. Names and experience profiles of the geosynthetic material manufacturer(s) and any installation contractors to be used on the project consistent with the requirements of Paragraph 1.04 B and C.

b. Qualifications and experience of installation personnel assigned to the project consistent with the requirements of Paragraph 1.04 B and C.

c. Manufacturer's factory MQC procedures as specified in Paragraph 1.04 E.

d. Product description, technical data, and catalog cut sheets for all materials to be supplied.

e. Material properties, chemical composition, roll dimensions and maximum roll weight after fabrication.

f. Recommended seaming procedures, material and equipment.

g. Recommended installation and repair procedures.

h. Certified test results that clearly show the ability of the GCL included in the submittal to meet or exceed the specified hydraulic conductivity and transmissivity.

i. Certified results of interface friction angle testing as specified in Sections 02777 and 01900.

j. Sample warranties for review and approval by The Owner, consistent with the requirements of Paragraph 1.02C.

2. SECOND SUBMITTAL: A minimum of 30 days prior to fabrication or shipment to the job site, whichever is sooner, the GCL

Manufacturer/Installer and Contractor shall submit the following information on the GCL:

a. Six (6) complete sets of site specific shop drawings showing seaming, anchoring, pipe penetrations, a comprehensive panel layout drawn to a scale that clearly shows panel configuration and any other design details required.

b. An Installation Plan including procedures for unrolling, unfolding, positioning, and field seaming; providing protection against the wind; and all other installation details necessary.

c. Fabrication details for any specialty shapes required.

d. Certification that all raw materials used in the manufacture of the GCL in the landfill liner system meet the requirements of the ASTM standards specified.

e. Two 3-foot square samples of each type of GCL material to be provided.

3. THIRD SUBMITTAL: At the time of delivery, the GCL Manufacturer/Installer and the Contractor shall submit the following information on the GCL material in the landfill liner system:

a. Certified laboratory test results documenting that the GCL materials provided meet the requirements specified herein and in the CQA Plan.

b. Certification that the materials, as manufactured and fabricated, conform to the shop drawings submitted previously and that the materials are free from manufacturing and fabrication defects.

4. FOURTH SUBMITTAL: Within 15 days after completion of landfill liner system installation, the GCL Manufacturer/Installer and the Contractor shall submit the following:

a. Certification of compliance with all liner system installation requirements specified herein and in the CQA Plan.

b. A written guarantee/warranty issued jointly by the GCL Manufacturer/Installer and the Contractor to the Owner as required in Paragraph 1.04 C.

c. As-built drawings of the landfill liner system, indicating all details and elevations of the completed installation, including the location of destructive test samples and other repairs.

d. A survey of the outside edge of the installed liner system, signed and sealed by a Registered Land Surveyor in the State of Florida.

PART 2--PRODUCTS

2.01 MATERIALS

A. GEOSYNTHETIC CLAY LINER

1. The GCL materials to be provided shall consist of the specified bentonite formulation encapsulated between two layers of geotextile.

2. On landfill surfaces with slopes flatter than 10H:1V, a non-reinforced GCL may be used. Non-reinforced GCL shall meet the minimum requirements set forth in Table 1 at the end of this Section.

3. On landfill surfaces with slopes steeper than 10H:1V, a GCL with needlepunched reinforcement betweenthe two geotextile layers shall be used. Reinforced GCL shall meet the minimum requirements set forth in Table 2 at the end of this Section.

4. The GCL Manufacturer/Installer and Contractor shall identify the limits of reinforced and non-reinforced GCL in the Installation Plan as required in Paragraph 1.06.B.2.b

PART 3--EXECUTION

3.01 DELIVERY AND HANDLING

Each roll of GCL shall be delivered in a protective outer covering and shall have a waterproof label containing the identification number, thickness, width, length, and proper direction of unrolling and/or unfolding. The Geomembrane Manufacturer/Installer

and Contractor shall be responsible for the repair or replacement of material damaged or made unserviceable during delivery and handling at no additional cost to the Owner.

The storage and handling of the GCL shall be in conformance with ASTM D5888 and the requirements of the CQA Plan in Section 01900.

The Owner will not accept delivery of materials until all required submittal information has been submitted and approved in accordance with Section 01300 and Paragraph 1.06 B and C of this Section.

Upon receipt of written authorization from the Owner, the Contractor shall deliver the materials to the area designated by the Engineer. This area shall be the Contractor's staging area provided by the Owner at no expense to the Contractor, for storage of material prior to and during installation.

3.02 INSTALLATION OF GCL

Panel placement should typically commence at the upgradient limit of work and progress in a downhill fashion. Rolls should be delivered to the active construction site in their original packaging. The panels may be placed by manually unrolling the GCL into position or by using heavy equipment. The panels should be oriented parallel to the line of maximum slope as much as possible. In corners and odd shaped geometric locations, the number of field seams should be minimized as practicable.

Installation of the GCL shall be in conformance with ASTM D6102 and the requirements of the CQA Plan in Section 01900.

Due to its weight, the GCL should be positioned as it’s unrolled. If the panel is being installed abutting a previously panel, care must be taken to align the sheets. When positioned, care must be taken to avoid damaging the bottom surface of GCL. A temporary smooth geomembrane or other geosynthetic covering, commonly known as slip sheet or rub sheet, may be used to reduce friction during placement.

Installed panels must be provided with a ballast to prevent their movement. Temporary ballast is usually provided in the form of sand bags placed along a seam. All GCL that is installed in a day must be covered with geomembrane that same day.

Table 1: Physical Properties for Non-Reinforced Geosynthetic Clay Liner

Property	Test Method	Units	Specified Value	Minimum MQC Testing Frequency
Components Prior to Assembly				
Bentonite Clay (as received)				
Swell index (minimum)	ASTM D 5890	ml	24	50 tons
Fluid loss (maximum)	ASTM D 5891	ml	18	50 tons
Moisture Content (maximum)	ASTM D 4643	percent	12	50 tons
Carrier Geotextile[(1)]				
Grab Strength (minimum)	ASTM D 4632	lb	60	200,000 ft^2
Mass per Unit Area (nominal)	ASTM D 5261	oz/yd^2	2.2	200,000 ft^2
Topping Geotextile[(1)]				
Grab Strength (minimum)	ASTM D 4632	lb	40	200,000 ft^2
Mass per Unit Area (nominal)	ASTM D 5261	oz/yd^2	2.7	200,000 ft^2
Finished GCL (as manufactured)				
Thickness (MARV)	ASTM D5199	mil	200	200,000 ft^2
Bentonite Mass per Unit Area (min) [3]	ASTM D 5993[(2)]	lb/ft^2	0.75	40,000 ft^2
Grab Strength (MARV)	ASTM D 6768[(2)]	lb/in	30	200,000 ft^2
Grab Elongation (MARV)	ASTM D 4632[(2)]	percent	10	200,000 ft^2
GCL Permeability[(4)] (max)	ASTM D 5887	cm/sec	5×10^{-9}	1 per lot
GCL Index Flux[(4)] (max)	ASTM D 5887	m/sec	1×10^{-8}	1 per lot
GCL Permeability[(5)] (max)	ASTM D 6766[(5)]	cm/sec	1×10^{-7}	1 per year
GCL Hydrated Internal Shear Strength (typical)	ASTM D 5321/ ASTM D 6243	lb/ft^2	100	1 per year

(1) ASTM method modified to use five specimens across the full roll width. The result is reported as the average of the five individual specimen results. Tensile testing is performed with specimens oriented in the machine direction.

(2) ASTM method modified to use five specimens across the full roll width. The result is reported as the average of the five individual specimen results measured at maximum peak in the weakest principal direction. ASTM methods are also modified as necessary for testing GCL instead of geotextile.

(3) Oven dried measurement.

(4) De-aired tap water at 5 psi maximum confining stress and 2 psi head.

(5) The GCL test specimen shall be hydrated with de-aired tap water, for a minimum of 24 hours using sufficient backpressure to achieve a minimum B coefficient of 0.9 and using confined effective consolidating stress not exceeding 5 pounds per square inch (psi). Then, the hydraulic conductivity test shall be conducted on the GCL specimen, using municipal solid waste landfill leachate as the permeant fluid, at a confined consolidation stress not exceeding 5 psi. The hydraulic conductivity test shall continue until steady state conditions are reached or a minimum of two pore volumes of permeate fluid have passed through the test specimen.

(6) Peak value measured at 200 psf normal stress for a specimen hydrated for 48 hours.

Table 2: Physical Properties for Reinforced Geosynthetic Clay Liner

Property	Test Method	Units	Specified Value	Minimum MQC Testing Frequency
Components Prior to Assembly				
Bentonite Clay (as received)				
Swell index (minimum)	ASTM D 5890	ml	24	50 tons
Fluid loss (maximum)	ASTM D 5891	ml	18	50 tons
Moisture Content (maximum)	ASTM D 4643	percent	12	50 tons
Carrier Geotextile[1]				
Grab Strength (minimum)	ASTM D 4632	lb	100	200,000 ft^2
Mass per Unit Area (nominal)	ASTM D 5261	oz/yd^2	3.2	200,000 ft^2
Topping Geotextile[1]				
Grab Strength (minimum)	ASTM D 4632	lb	15	200,000 ft^2
Mass per Unit Area (nominal)	ASTM D 5261	oz/yd^2	6	200,000 ft^2
Finished GCL (as manufactured)				
Thickness (MARV)	ASTM D5199	mil	200	200,000 ft^2
Bentonite Mass per Unit Area (min) [3]	ASTM D 5993[2]	lb/ft^2	0.75	40,000 ft^2
Grab Strength (MARV)	ASTM D 6768[2]	lb/in	30	200,000 ft^2
Grab Elongation (MARV)	ASTM D 4632[2]	percent	10	200,000 ft^2
Peel Strength (minimum)	ASTM D 6496	lb/in	2.3	40,000 ft^2
GCL Permeability[4] (max)	ASTM D 5887	cm/sec	5×10^{-9}	1 per lot
GCL Index Flux[4] (max)	ASTM D 5887	m/sec	1×10^{-8}	1 per lot
GCL Permeability[5] (max)	ASTM D 6766[5]	cm/sec	1×10^{-7}	1 per year
GCL Hydrated Internal Shear Strength (typical)	ASTM D 5321/ ASTM D 6243	lb/ft^2	500	1 per year

[1] ASTM method modified to use five specimens across the full roll width. The result is reported as the average of the five individual specimen results. Tensile testing is performed with specimens oriented in the machine direction.

[2] ASTM method modified to use five specimens across the full roll width. The result is reported as the average of the five individual specimen results measured at maximum peak in the weakest principal direction. ASTM methods are also modified as necessary for testing GCL instead of geotextile.

[3] Oven dried measurement.

[4] De-aired tap water at 5 psi maximum confining stress and 2 psi head.

[5] The GCL test specimen shall be hydrated with de-aired tap water, for a minimum of 24 hours using sufficient backpressure to achieve a minimum B coefficient of 0.9 and using confined effective consolidating stress not exceeding 5 pounds per square inch (psi). Then, the hydraulic conductivity test shall be conducted on the GCL specimen, using municipal solid waste landfill leachate as the permeant fluid, at a confined consolidation stress not exceeding 5 psi. The hydraulic conductivity test shall continue until steady state conditions are reached or a minimum of two pore volumes of permeate fluid have passed through the test specimen.

[6] Peak value measured at 200 psf normal stress for a specimen hydrated for 48 hours.

END OF SECTION